

CLIMATE CONTROL IN DESIGN OF THE KANSAS HOME

by

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INTRODUCTION

Over the past one hundred and fifty years, houses in Kansas have been designed and constructed with apparent disregard to some of the major climate problems present in the state. In early years, emphasis was placed on using native materials, timber in the eastern two-thirds and sod in the western third. Although the nature of these materials sometimes fitted them for construction in the Kansas climate, this fact was in most cases incidental to ease of procurement. Sod houses in Western Kansas, with their thick layer of soil on the roof, proved to be a fair insulation against the Kansas sun, however the apparent defects of sod as a permanent building material prohibited its use for more extensive residences and buildings.

In later years, the designs of Kansas houses were borrowed from those eastern states, which very often had a climate much different from Kansas. Stereotyped homes such as the one and one-half story "Tee" shaped house sprung up on thousands of Kansas homesteads. These houses are now sometimes more than seventy-five years old and unless consideration is given to the control of the Kansas climate, the occupant of their replacement may be only slightly more comfortable than in the old building.

In recent years, architects and designers have given considerable attention to the design of the house in relationship to the surroundings. Relating the house to the Kansas prairies has been a large factor in the design and the building as a means of climate control has often become secondary. Because it is assumed that any deficiency in design can be compensated for by mechanical heating and cooling, the design many times no more represent a home for Kansas than the New England Cape Cod cottage or a Swiss mountain lodge.

Mechanical means of climate control are conceded as a permanent requirement in residential design, however because of the high cost of equipment and operation, it is the premise of this thesis that all means should be explored and all measures taken to reduce the load on this equipment and supplement it so that the actual cost of the initial installation and operation may be reduced.

The purpose of this thesis is not to design a prototype building that will be the panacea for all climate control problems. Its purpose instead is to show that where climate data is available, it is possible to utilize the structure of the home itself as a climate control tool and at the same time introduce proven features and the authors theories into the design.

MATERIAL AND METHOD

The thesis will demonstrate climate control through the design of the Kansas home by the process of designing a house for one particular locality in Kansas. For the purpose of the problem, a hypothetical situation has been given which is similar to a great many families in that area. The problem locale is in Western Kansas in Finney County and a complete analysis of climate data for that area will be given. Data of this type is also readily available for any other portion of Kansas.

THE PROBLEM

The essence of this problem is to design a house for a certain region taking advantage of all climatic assets and making special recognition of the adverse conditions that prevail in this particular area. Although it is assumed that many unfavorable or uncomfortable conditions can be remedied

mechanically or artificially, consideration will also be given to the fact that the cost of this type of remedy is often times high. For that reason, the approach will be taken that a great deal of savings can be affected through design of the structure itself, the materials used, and a thorough application of a knowledge of prevailing climatic conditions. While it will not be expected that design alone will make the residence comfortable at all times of the year, it must make the use of mechanical equipment unnecessary for a greater period of the year and when such equipment is needed it must make its use more economical.

Locale

The home of this problem is located in Finney County, Kansas. Finney County is in the west center of the western third of the state and in the southern half of that portion. This places it approximately 38 degrees longitude and 101 degrees west latitude. The terrain consists of mostly flat lands or low rolling hills. Wooded areas are at a minimum, most of them being along the Arkansas river which flows across the middle of the county east and west. Ground cover consists mainly of sorghum crops and wheat or grassland.

The location more specifically is 13 miles east and 6 miles north of Garden City, the county seat. The site is just west of a gravel secondary road on a slight rise. There is a wooded creek three quarters of a mile to the southwest with low hills beyond. The land is flat to the east and north. There is no natural protection from either terrain or foliage.

The Site

The site itself, as shown on Plate I, is for all practical purposes, level although there is a slight slope to the southwest. There are only two existing buildings on the site, one of which is the present residence which will be removed. This house sets about 100 feet from the gravel road with a large machine shed, approximately 200 feet straight west. This shed is about 30 feet by 80 feet running east and west. About fifty feet north of the machine shed are the remains of a shelter belt. It consists of two rows of red cedars reaching from the shed east to within 40 feet of the road. There are several trees scattered about the existing house. These are mostly cottonwood and elm. The location for the new house has been selected directly south, about 200 feet, from the southeast corner of the machine shed. This still places it on the level portion of the rise with about 100 feet to the south and west before the level ground falls off at all. There are no trees at all in this location and the ground cover is native grasses.

There is a good supply of water available, the well being west of the machine shed. This well has always provided plenty of water even in years of drouth, both because of the quality of the well and because it has been and will be used only for domestic water and lawn use.

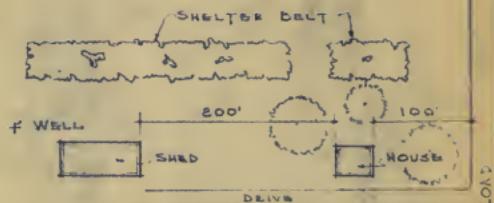
The soil is a sandy loam and there is no appreciable amount of rock in the sub-surface.

From the new homesite there is a reasonable view to the south and west. As the ground falls away, there are fields of wheat and some sorghum crops and beyond that a small creek that is wooded. Several bluffs and cliffs can be seen along its course and beyond it are rolling hills of grassland. The farmstead and farm court are now located to the north and the gravel road

EXPLANATION OF PLATE I

Plan of existing site and buildings showing
the proposed location of the new home.

PLATE I

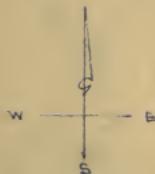


LEVEL GROUND ↗

300'

PROPOSED LOCATION
OF NEW HOME

↗ GROUND BEGINS TO DROP OFF



with flat wheat fields are to the east. There are several homes visible to the east but they are not close enough to affect the design of the home. There are two homes a half mile to the north, but are hidden at the present by the machine shed and shelter belt.

Access to the home site must necessarily come from the east although this access road may be adjusted anywhere within a 200 yard frontage to suit the design. There is no problem of crossing the ditch at the gravel road.

The Family Program

The family numbers five and consists of the husband, wife, two boys, 15 and 8, and a daughter, 10. The business is farming and this covers mainly crops. There is no livestock program. The family operates two cars, one belonging to the oldest son.

The family life in general is informal; they entertain quite often with card parties and many very casual get togethers with the neighbors. The older son and daughter both have friends in often and require entertainment space apart from the quiet portions of the home. The whole family likes to read and all enjoy quiet evenings with a book. Television has come and gone with this family and it now is used only on occasion and is not depended upon for nightly entertainment.

Besides liking to cook, cooking is a necessity for the mother and daughter of helping age, therefore plenty of room must be provided in the kitchen. There are times when hired help is served at the table. This takes place mostly in the summer months during July and August. Office space for the husband must be furnished although a separate room is not necessary.

There is no prospect of more children and no chance of the addition of

grandparents to the family. The family is moderately wealthy and can afford a house of \$40,000 to \$60,000. The designer may have a free hand in the design of the house as long as it satisfies the requirements of their way of life and provides a home that recognizes the climate and environment.

THE CLIMATE

Foremost in the problem of designing a building primarily to reflect the surrounding climatic environment, is a collection of climate data for that particular area. To understand the complete climate problem a knowledge of the geographical background is necessary.

The area involved in this thesis, Finney County, Kansas, is located in the western third of the state which has three rather distinct climates outlined roughly by its Eastern, Middle, and Western Thirds. The western third is often called 'The short grass country' because of the prevalence of buffalo grass in that section. It has an elevation rising from about 2000 feet at its eastern border to nearly 4000 feet in some northwestern counties and an average annual precipitation of 19.01 inches. The air here is almost as dry and bracing as in summer resorts of the Rocky Mountains. The amount of sunshine exceeds that of almost any part of the country except the southwest. The wind movement is rather high and the range between day and night temperature is considerably greater than points farther east. The above information and the following data are taken from Flora (9) and the U. S. Department of Agriculture (23).

Temperature

In designing a residence that will most effectively combat the elements

of the surrounding territory, it is essential that the architect know what to expect in the way of temperature. This must include not only the extremes of heat and cold, but also average daily temperatures in daylight hours and at night. Also of utmost importance, to the architect concerned with the control of climate, is exactly when these temperatures occur. For example, it would be of great help in designing sun controls to know exactly when the average outside temperature becomes higher or lower than the ideal indoor temperature. Also when the temperature at night becomes too cool or hot to be used as circulated air inside the house.

Finney County has a normal annual mean temperature of 54.9 degrees and an average daily range of 30 degrees in July and an average daily range of 28 degrees in January. For purposes of calculating heating loads, Finney County has an average of 5000 degree days annually.

Tables 1, 2 and 3 give the monthly normal temperatures, the mean maximum temperatures and the mean minimum temperatures.

Table 1. Monthly normal temperatures.

Jan.: Feb.: Mar.: Apr.: May: June: July: Aug.: Sept.: Oct.: Nov.: Dec.
30.9 34.2 43.8 54.0 63.7 73.4 78.4 77.8 69.6 56.5 43.0 32.6

Table 2. Mean maximum temperatures.

Jan.: Feb.: Mar.: Apr.: May: June: July: Aug.: Sept.: Oct.: Nov.: Dec.
45.1 49.1 59.5 69.4 78.1 87.7 93.7 92.5 84.6 72.4 58.7 46.6

Table 3. Mean minimum temperatures.

Jan.: Feb.: Mar.: Apr.: May: June: July: Aug.: Sept.: Oct.: Nov.: Dec.
16.6 19.2 28.1 38.5 49.2 59.1 64.2 63.1 54.6 40.1 27.2 18.6

Finney County has recorded a record high of 113 degrees on July 13, 1934 and a record low of -32 degrees on February 12, 1899.

The Sun

Along with the temperature, the amount of sunshine available is one of the most important climatic factors under consideration by the architect when designing a residence for a certain area. In Kansas, this is especially true due to the large amount of solar energy that is absorbed in this state from radiation.

Kansas as a whole, is favored with more clear and fewer cloudy days than any state to the east or north of it. Finney County averages 100 partly cloudy days a year, 50 cloudy days a year and 215 clear days. During winter, when this difference is especially marked, it results in more pleasant weather. This also makes the solar energy a very good source of heat if properly controlled and at the same time produces a terrific comfort problem in the summer months.

Table 4 shows the exact position of the sun at all times of the year at every hour of the day for Finney County. The sun position table is equipped with a time corresponding to solar time. In other words the position of the sun at 12:00 noon is due south. Due to the location of Finney County in relation to the meridian, longitude 90 degrees west, from which central standard time is calculated, the time in Finney County will be 44 minutes ahead of this and must be converted to solar time to get a correct reading from the table. To do this, one merely subtracts 44 minutes from local time to get solar time.

Table 4. Angles and bearing of the sun.

TIME	Dec			Jan			Feb			Mar			Apr			May			June			
	21	11	1	21	11	1	21	11	1	21	11	1	21	11	1	21	11	1	21	11	1	
5:00am	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	
6:00am																						
7:00am																						
8:00am																						
9:00am																						
10:00am																						
11:00am																						
12:00pm																						

A indicates altitude of sun in degrees.

B indicates bearing from true South in degrees,
East if A.M., West if P.M.

The Wind

With regard to comfort and structural safety, wind is another element of climate that is of considerable interest to the architect designing for a certain region. The two aspects of the wind that will be concerned with in this study are direction, or where it comes from, and the speed, both of which are combined in one term, velocity.

Finney County, along with most of western Kansas, has an average wind movement that ranks close to that of western Oklahoma and the Panhandle of Texas and the windiest inland area in the country except around the Great Lakes and in isolated mountain locations.

The average wind velocities for each month of the year are indicated in Table 5.

Table 5. Average wind velocities in miles per hour.

Jan.: Feb.: Mar.: Apr.: May: June: July: Aug.: Sept.: Oct.: Nov.: Dec.
11.9 12.5 14.3 14.9 13.6 14.1 12.2 12.2 13.1 12.3 12.5 11.9

These readings were taken in Dodge City, Kansas, located approximately 50 miles to the southeast. Although this table gives an idea of the continuity of fairly high winds and when the highest winds occur, it does not tell the whole story. There is a marked variation in wind through the hours of the day. The movement increases during the hottest period of the day and falls off during the night, the highest velocities occurring around three o'clock in the afternoon and the lowest at six o'clock in the morning.

A building designed for this area must of course withstand wind velocities much higher than the averages shown. Maximum speeds of close

to 65 miles per hour have been recorded and it is possible that there have been non-recorded gusts of even higher.

Table 6 gives the prevailing wind direction during the year. This data was also collected at Dodge City.

Table 6. Wind directions.

Jan.: Feb.: Mar.: Apr.: May: June: July: Aug.: Sept.: Oct.: Nov.: Dec.											
NW	NW	NW	SE	S	SE	S	S	S	S	S	NW

While discussing wind conditions in and around Finney County, it would be well to mention the storm commonly known as a "cyclone" or the tornado. A tornado is the most violent, least extensive and most sharply defined of all storms. Although several are seen in this portion of the state each year, the area they cover makes the odds against any one square mile being hit by one better than 1 in 1643. The tornado is distinguished by a funnel shaped, vortex cloud revolving at a terrific speed which has never been measured. Calculations made from damaged buildings and steel sections indicate to some people that this speed exceeds 500 miles per hour.

Tornadoes travel a slow course, usually from the southwest to the northeast, although they have been known to come from any direction. Usually they move along their paths from 30 to 40 miles per hour but sometimes they have been known to slow down to a halt. They occur at all hours of the day but are most frequent from 5:00 p.m. to 7:00 p.m.

Precipitation

Although the change in temperature that accompanies most forms of precipitation is probably of more interest to the architect than the amount

of moisture itself, there are several advantages and disadvantages of precipitation that should be considered by the architect before he completes the design for a certain area. Jeffery Ellis Aronin (1) outlines these advantages and disadvantages as follows:

Advantages

- Insulation qualities of snow
- Moisture is a cooling agent
- Rain washes away dirt.
- Psychological effect, aesthetics
- Reflects beneficial radiation

Disadvantages

- Snow can pile up in unwanted places
- Moisture is damp and annoying
- Possible floods by showers themselves or by the consequent overflowing of rivers, streams and lakes
- Sleet is hazardous
- Damage from hail

Precipitation is usually present in Finney County in the form of rain in the summer and snow in the winter, the amounts of which were briefly stated earlier in this work. However it will be of benefit to anyone wanting to use above mentioned advantages to know in which parts of the year most of this precipitation occurs.

From 70 to 77 percent of the annual total falls during the six warmer months of the year from April to September. In and around Finney County the average fall is 14.70 inches. The average inches of precipitation for each month in Finney County is shown in the following table.

Table 7. Precipitation in inches.

Jan.:	Feb.:	Mar.:	Apr.:	May:	June:	July:	Aug.:	Sept.:	Oct.:	Nov.:	Dec.
.35	1.86	1.02	2.05	2.58	2.95	2.54	2.22	1.91	1.25	.76	.50

This gives an annual average of 19.93 inches, however the wettest year of record, 1915, gave a total of 28.14 inches of precipitation and the driest year of record, 1936, gave only 14.12.

Snowfall in Kansas averages less than any state to the west of it except Arizona and possibly California and less than that of any other state east of the Rockies located north of the northern border of Arkansas and the Ohio River. The average annual snowfall for Finney County is 18 inches, however there are periods when a great deal of snow may fall in a very short time. In 1912, 14 inches fell in a 2½ hour period. The greatest depth of snow ever to be measured on the ground was 18 inches in 1903. This low amount is due mostly to the rather frequent sequence of a mild weather even in the midwinter months.

The average number of days when the ground is covered with snow is 23, however in 1918, there were 46 days in a row when there was one inch or more of snow on the ground.

Hail in western Kansas is nearly four times more frequent than in the rest of the state which usually has no more of this type storm than the rest of the country. These hail storms usually follow the rains and occur mostly in the summer months. The stones from these storms are usually small, ranging in size from that of peas to gold balls but occasionally they reach the size of baseballs. Hail of this type can cause considerable damage to glass areas exposed to them.

Other Climatic Factors

Relative Humidity. The average relative humidity around Finney County, especially during daylight hours and early evening, is less than that of any

state lying entirely east of the Continental Divide of the Rockies. This results in the climate being drier and more bracing with fewer muggy, sticky days during the summer and less damp weather in the winter than in the states of the East and South. The lowest relative humidity occurs from 11:00 a.m. to 6:30 p.m. Average midday and early evening relative humidity around Finney County in July ranges from 35 to 40 percent and in the winter season it ranges somewhat higher at those hours, nearly 60 percent.

Table 8 indicates the mean relative humidity for each month of the year at different times of the day.

Table 8. Relative humidity.

Jan.: Feb.: Mar.: Apr.: May: June: July: Aug.: Sept.: Oct.: Nov.: Dec.												
<u>12:30 a.m.</u>												
75.9	73.3	72.0	71.9	76.0	72.0	63.4	69.3	65.6	69.9	69.3	76.0	
<u>6:30 a.m.</u>												
77.4	75.8	74.5	75.4	79.2	76.4	69.9	73.4	75.2	75.1	73.3	77.7	
<u>12:30 p.m.</u>												
57.0	53.1	47.6	46.2	48.1	45.9	36.5	39.9	43.4	43.5	46.7	55.7	
<u>6:30 p.m.</u>												
61.7	56.2	46.7	45.0	48.2	43.7	35.3	39.3	44.3	49.5	53.6	63.3	

These figures for relative humidity were taken at Dodge City, Kansas. The low relative humidity that this area of Kansas enjoys favors rapid evaporation. This fact can be turned to the advantage of an architect using this principal for cooling purposes. Weather bureau records show the following average amount of evaporation in inches during the summer months in Garden City.

Table 9. Evaporation in inches.

April	:	May	:	June	:	July	:	August	:	September
6.474		8.308		10.010		11.689		10.350		8.015

Dust Storms. Another climatic phenomenon while not peculiar to Kansas but which does occur in Finney County, is the dust storm. Although it can be assumed that in the future, better farming practices may control the blowing of dust, at the present it is a matter to be concerned with, particularly since they occur in the dry month of March and sometimes carry over into April and May. This would certainly hamper any attempt to use natural ventilation for cooling purposes. The dust naturally follows the wind and tends to die down in the evenings.

ANALYSIS OF DESIGN

Having determined the climatic factors of Finney County and considering the personal activities of the family involved the following house was designed. Plate II indicates some of the factors affecting the design of the residence.

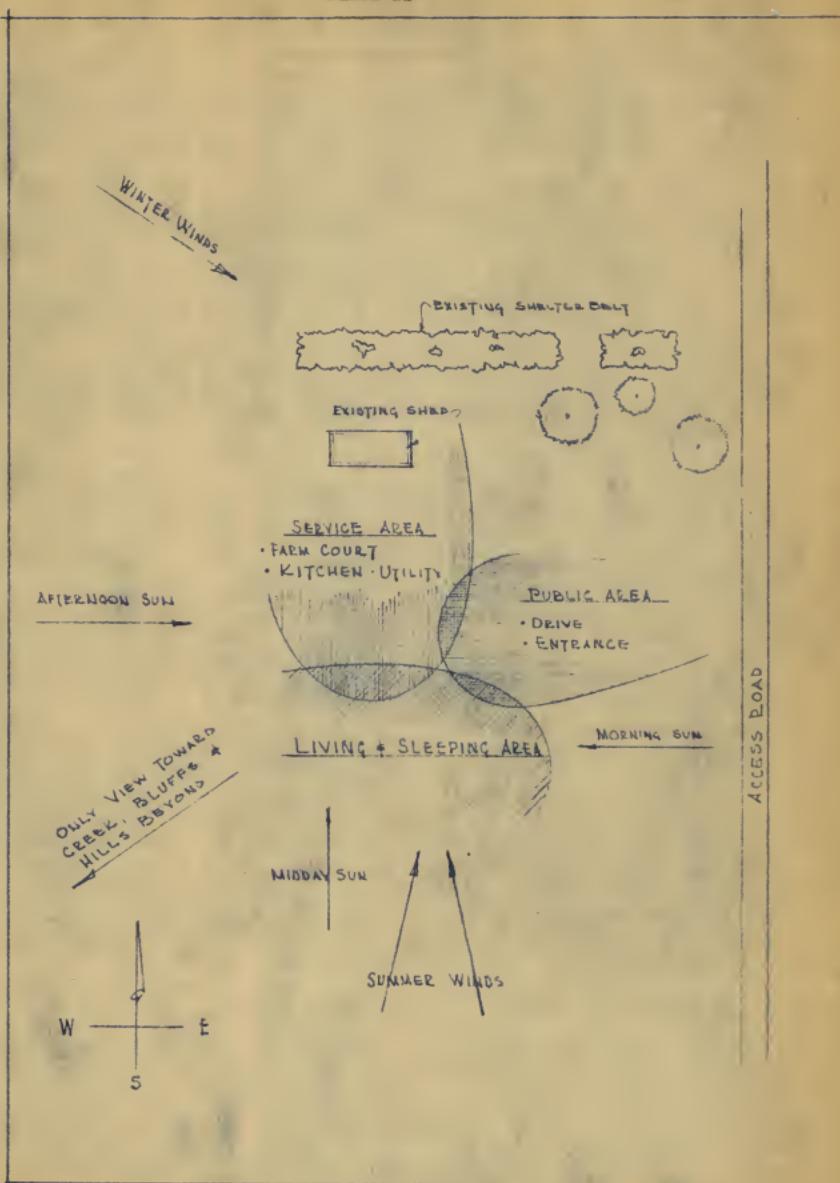
The Plan

Plate III shows the plan of the proposed building. The double garage has been placed north of the main structure to serve as a barrier from prevailing winter winds. The service area; kitchen, eating, laundry and cleanup room, was located directly south of the garage with access through the garage to the outbuildings toward the northwest. Although this means using two doors, it makes use of the garage for the purpose of removing muddy boots and overshoes

EXPLANATION OF PLATE II

Design Factors of Site

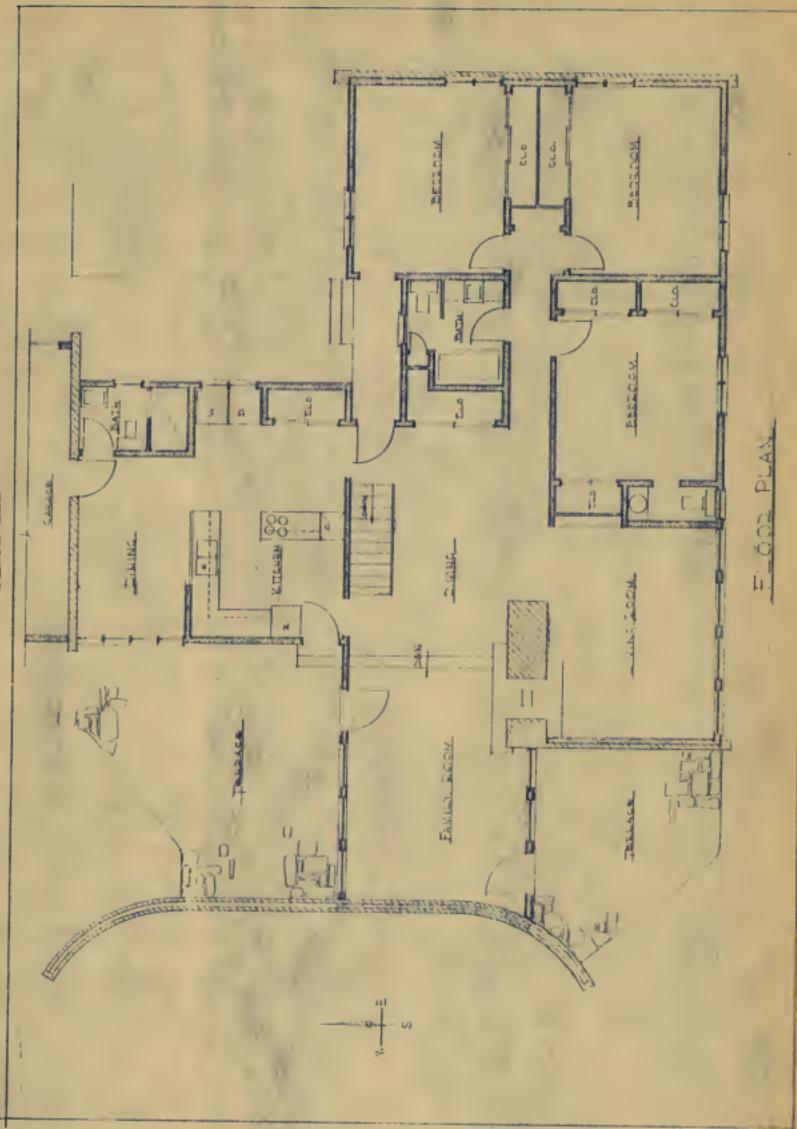
PLATE II



EXPLANATION OF PLATE III

Floor plan of the house

PLATE III



which will be essential on a farm both summer and winter. This area has window openings on the west, the only ones in the house, to obtain a direct view of the farm court and also on the east to bring in a view of the drive and access road beyond. The eating area is adequate for most meals even when the work force is expanded for harvest and a door has been provided for egress from the kitchen to a terrace on the west. This terrace may also be used for harvest meals, taking advantage of the balmy climate prevalent during the July harvest season.

South of the service area was located the living and sleeping areas. Because of the families habits and activities, the formal living room was designed as a smaller, quiet room, more like a den or library, yet still suitable for formal receiving and entertainment of small groups. This room is opened to the south to attain sun control and is completely closed on the west. The family-dining room is an informal living area with the family room dropping down two steps to terrace level. This room may be opened onto the kitchen terrace or to a south terrace which takes advantage of the only view to the southwest. The family room too, is closed on the west and opened only on the north and south. These openings also provide the maximum summer natural ventilation. There is access to the dining room from the kitchen through two openings, one directly from the food preparation area and the other in the main traffic line from the garage.

The main entrance is also located in this area, as is the basement stairs. The entrance, although recessed to protect it from winter winds, is so located that it is easily discernible from the approach and drive.

Two of the three bedrooms were located on the south to take advantage of the prevailing summer breeze and all are on the south or east to prevent

excessive heat gain from the late afternoon sun.

The living and sleeping area, the largest structural portion of the house, was oriented east and west to present the least amount of wall possible to the western sun. Studies (3, 6, 14, 17, 19) indicate that complete solar control on the west by fixed shading devices are so cumbersome as to nearly make them impractical. Since there is no great need for a view in this direction this wall is devoid of openings of any kind. The longest portion of this area facing south, lends itself to the simplest type of control, the horizontal roof overhang. Sun positions for Finney County as indicated by the Libby-Owens-Ford Sun Angle Calculator (13) show the practicability of this type of shading device.

Both terraces, while being on the west are shaded from late afternoon sun by extensions of the west wall of the family room. The extension on the south is curved out to facilitate the view to the southwest and is repeated on the north.

Casement windows were used throughout because of the ventilation advantages in their favor.

1. When they are open, the total window area is exposed.
2. They are directional and can be used to direct a stream of air flowing parallel to the window wall.

Structure

In designing the structure of the house several premises were made.

1. The climate data for Finney County shows that there are a large number of clear, hot sunny days during the summer with temperatures averaging higher than would normally be comfortable from the first part of April to the middle

of September. Although there is a larger degree differential between the average winter temperature and the desired indoor temperature, 75 degrees to 80 degrees, than between the summer average and indoor design temperatures, Conklin (4) states that it is five times as costly to remove one degree of heat from a building as it is to add one degree. Therefore emphasis was placed on protecting the building against summer heat gain.

2. Most of the heat gain in the summer comes through the roof, which not only must serve as a thermal barrier between outside and inside temperature, but must receive the largest portion of the radiant solar energy from the sun. Therefore, design measures were concentrated in the roof structure.

3. In normal roof structures which are designed for warm climates, consisting of an attic space in one form or another, a problem exists due to an increase of temperature in this space. This temperature may raise to 150 degrees or over during a day of 90 degree outdoor temperature, Groff Conklin (4). In an investigation of the definition of heat transmission, "U" = B.T.U. transmitted/hr./sq.ft./degree difference in temperature, it can be seen that heat loss is dependent upon two varying factors. One, the heat transmission factor of the material involved which goes to make up "U" and the other, the difference in temperature between one side of the material and the other. In the case of a ceiling insulated with mineral wool to give a "U" value of .05, the heat loss over 1000 square feet would be 35,000 B.T.U. in a 10 hour period if the attic temperature was 150 degrees. This is assuming a 90 degree day, and indoor design temperature was 80 degrees.

$$\text{B.T.U.} = .05 \times 1000 \text{ sq. ft.} \times 10 \text{ hr.} \times (150^\circ - 80^\circ) = 35,000$$

By adding insulation, the "U" factor could possibly be lowered to .03

although this might be difficult in some structures. The heat loss in this case would be reduced to 21,000 B.T.U.

$$\text{B.T.U.} = .03 \times 1000 \text{ sq. ft.} \times 10 \text{ hr.} \times (150^\circ - 80^\circ) = 21,000$$

Even considerable insulation results in just a fractional reduction of the "U" factor, however if it would be possible to reduce the temperatures difference to that between the normal outside temperature of 90 degrees and the inside temperature of 80 degrees the resulting heat loss could be reduced to 5000 B.T.U. over the 10 hour period.

$$\text{B.T.U.} = .05 \times 1000 \text{ sq. ft.} \times 10 \text{ hr.} \times 10^\circ = 5,000 \text{ B. T.U.}$$

Thus the heat loss is reduced 30,000 B.T.U. in a 10 hour period when the excess attic heat is taken away as compared to a heat loss reduction of only 14,000 B.T.U. when the "U" factor of the ceiling is reduced .02. Therefore it was decided to make all attempts to design out the excessive attic temperature in the roof structure.

Since climate data showed a strong average wind velocity during the summer months, it was decided to take advantage of this to actually blow the hot air out of the attic of the home. The major portion of the building being orientated to the east and west, it did not lend itself to opening the gable ends as ventilators. Since the prevailing winds in the summer are from the south, a roof structure was needed that facilitated opening the roof on the south and north which, in this case, would be along the eave line.

The Roof

Plate IV shows the major breakdown of the conventional roof systems

EXPLANATION OF PLATE IV

General roof types

PLATE IV

DOUBLE SLOPE

FIG. 1. GABLE WITH ATTIC SPACE

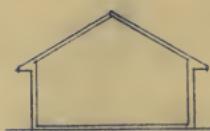


FIG. 2. GABLE WITHOUT ATTIC SPACE



FIG. 3. BUTTERFLY WITHOUT ATTIC SPACE

SINGLE SLOPE

FIG. 4. SHED WITH ATTIC SPACE



FIG. 5. SHED WITHOUT ATTIC SPACE

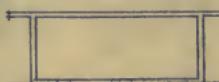


FIG. 6. FLAT DECK WITHOUT ATTIC SPACE

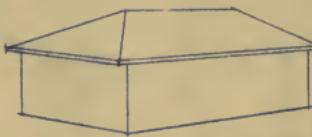
FOUR SLOPE

FIG. 7. HIP WITH ATTIC SPACE

available to the designer when selecting such a system to satisfy the requirements or to remedy the faults as set forth in the previous premise. Each of the systems have, upon investigation, certain advantages and disadvantages which might or might not qualify them for the purpose of controlling the climate in this problem.

The gable roof with a ceiling enclosing an attic space, Fig. 1, gives the air space necessary to keep heat absorbed by the roof deck from being transmitted directly to the ceiling and insulation. It also has a space at each gable in which to place ventilating louvers, although this space is limited. This roof has the disadvantage of having the venting louvers oriented in the wrong direction for this problem since they would be located in the east and west ends and at right angles to the prevailing winds. It also has the disadvantage of having to maintain a steep pitch in order to provide sufficient space for the louvers in the gables. This steep pitch is expensive in the use of materials and gives the house a feeling of added height that may be undesirable in a location or primarily level ground.

The gable roof without an attic, Fig. 2, is more economical than the aforementioned system, but it has the serious disadvantage of not providing space for an air insulator of any dimension. This is also true of the butterfly roof, Fig. 4, which is seldom if ever used with a ceiling and resulting attic space.

The single slope roof lends itself to venting into the attic space along the south side of a building when the long side is oriented in that direction, however the only outlets for the incoming air would be at the ends and there would be a tendency to form an airtrap under the roof. Without an attic, as in Fig. 5, this roof has the same disadvantages as Fig. 2

and 3. The flat deck in Fig. 6 also suffers from these faults and is hard to insulate as will be shown later in this thesis. In any roof structure where the ceiling follows the line of the roof rafters, there is the possibility of using the roof deck itself as the finish ceiling, leaving the rafters exposed. This means that any insulation must be placed on the exterior and this usually means that a rigid board insulation must be used which is several times more expensive than the batt type which may be placed above a suspended ceiling. Even when the ceiling follows the bottom edge of the rafters and insulation leaves an air space above it, this air space is so small that radiant heat easily reaches the insulation and the heated air in the space is difficult to remove.

The four slope or hip roof in Fig. 7 provides plenty of airspace in the attic and even presents a considerable amount of under eave ventilation space. This type of ventilation does not take advantage of all the air movement available and usually needs auxillary vents to remove the heated air. Even with these complete and effective air removal must be accomplished with mechanical equipment.

To satisfy the requirements of air removal and to take advantage of the prevailing southern winds a roof structure was designed as a combination of the single slope shed roof and butterfly roof.

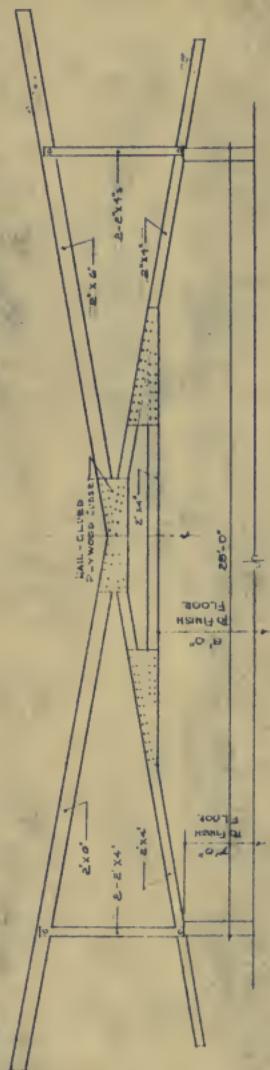
Plate V shows the roof truss for this type of structure. These trusses would be placed four feet on center with intermediate rafters and ceiling joists placed on sixteen inch centers between them.

The space between the upper and lower cords of the trusses were filled both north and south with louvers. The louvers were placed in the four foot space between the trusses. Plate VI shows the detail of the selected louver.

EXPLANATION OF PLATE V

Roof Truss

Tome V

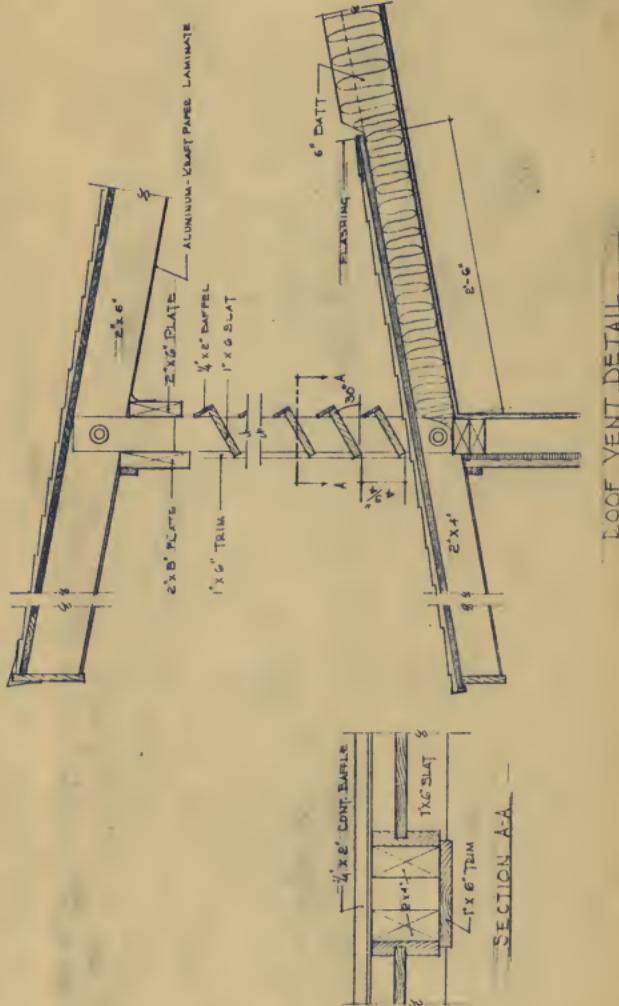


200F TRUSS

EXPLANATION OF PLATE VI

Detail of ventilating louver

PLATE VI



Tests by the Small Homes Council (12) indicate that although commercial stormproof louvers are available that virtually eliminate all rain and snow entry, the cost is high and the ventilation value is relatively low. A louver slanted at 30 degrees with the horizontal was chosen to give the best air passage and yet give a fair degree of rain and snow protection. A rear lip was added to increase this protection and although a similar lip on the front of each louver would make a completely weatherproof louver, it would reduce air flow. Since a free flow of air was essential to the success of the roof, the lip was left off and the roofing surface covering the overhang of the lower cord was extended 2'6" into the attic to catch all fine rain and snow spray. Any such trapped spray would simply drain under the louvers to the eave.

The whole truss was lowered to give a ceiling height of 7'0" at the outside wall line. This was done to reduce the length of the overhang necessary to shade the south windows.

The roof surface is a white composition shingle chosen because of test results reported by the National Bureau of Standards (5) which indicates the white color will give a very low rise in temperature as compared to dark colors. Although a smoother surface such as sheet metal painted white would be better, the daily differential of temperature in this area make expansion of sheet metal very difficult to control.

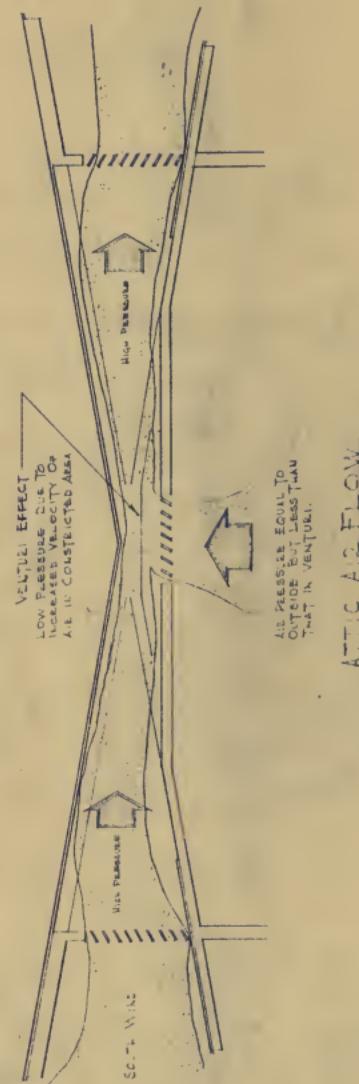
The Venturi Effect

Plate VII shows the air flow through the attic space. The shape of the attic space constricts the flow of air at the center line of the truss creating a low pressure area at this point and a venturi effect. By opening the ceiling

EXPLANATION OF PLATE VII

Illustration of the venturi effect in the attic.

PLATE VII



at this low pressure point a flow of air will be created from the rooms in the center of the house due to the pressure differential between the two areas. When a breeze is blowing from the south and the temperature is favorable, natural ventilation and cooling of all rooms may be maintained in this way; open windows in the south rooms and flow of air through the attic from the north rooms and hall way.

This natural ventilation is important in Finney County even in the middle of the hottest months due to the cooling effect of the night air which sometimes drops over 30 degrees. This type of cooling is also desirable and possible because of the low relative humidity in this part of Kansas.

Elevations

Plates VIII and IX show the effect of the aforementioned roof trusses on the elevations. The east and west elevations indicate the extended upper and lower cord of the truss which serves a dual purpose of shading the south windows and acting as an air scoop for the ventilating louvers. The west elevation clearly shows the absence of windows exposed to the western sun. The one exception is the kitchen window which is protected by a sun screen that can also be seen on this elevation. Its function will be described in the next section. The windows on the south wall of the family room have been left above the patio floor to keep dust and trash from the glass.

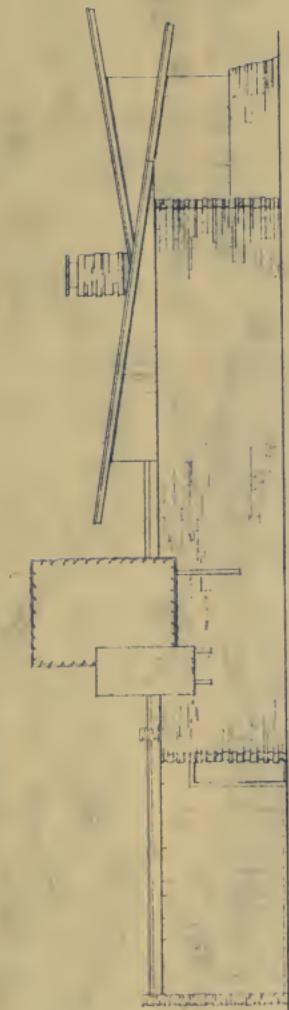
Solar Control

Climate data indicates that summer temperature and the average number of summer days dictate that complete control of solar energy during the summer months is a necessity. Temperature tables show that April 11th and September

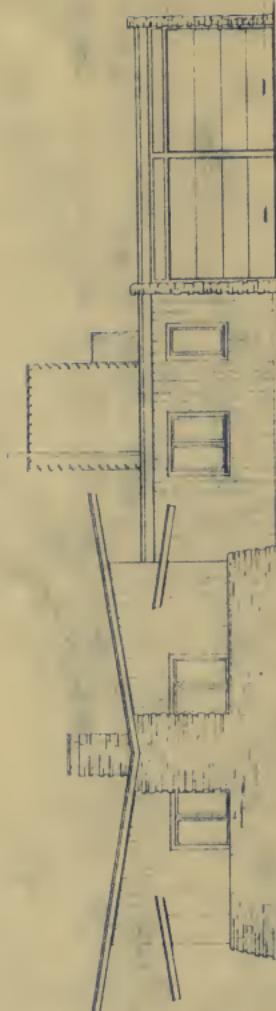
EXPLANATION OF PLATE VIII

East and west elevations of the house.

PLATE VIII



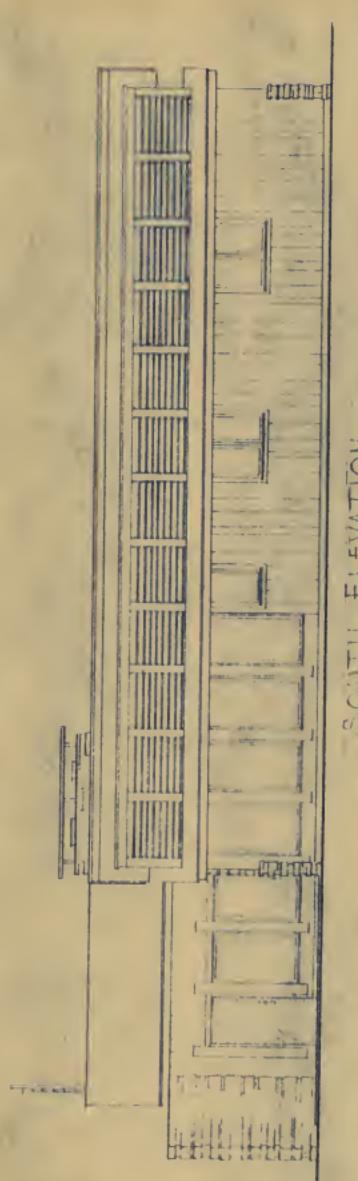
WEST ELEVATION



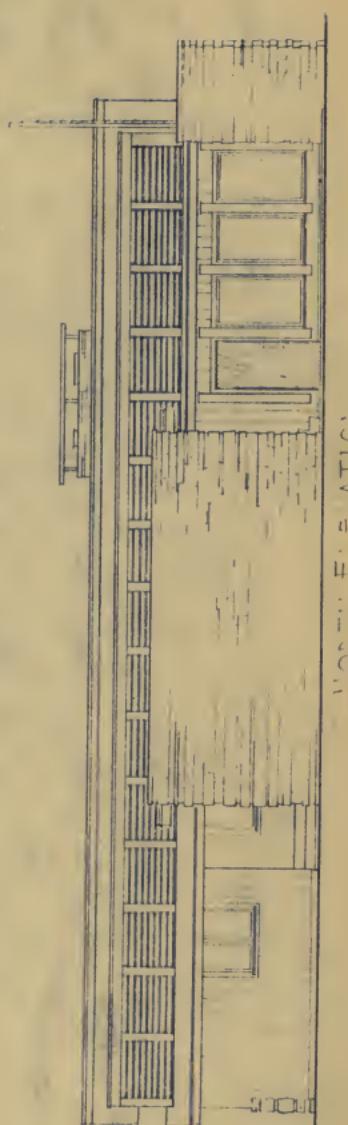
EAST ELEVATION

EXPLANATION OF PLATE IX

North and South elevations of the house.



SCOTTISH ELEVATION



W. G. E. ELEVATION

1st may be the limits of complete control. It is between these dates that average outside temperatures are higher than comfort would allow. It is during this time that mechanical cooling will be necessary much of the day and to make this operation as economical as possible it is desirable that all window openings be shielded from the direct rays of the sun. Plate X shows the shade on the south wall and windows between April 11th and September 1st. This shade is accomplished by the overhang of the lower truss cord. All shading and screening was calculated with the help of the Sun Angle Calculator (13) and the sun table at the beginning of this thesis. Plate XI shows the shade on the kitchen window cast by the sun-screen fastened to the west masonry wall. This screen could be made of several different materials. In this case a portion of it contains a canvas panel which can be taken down in the winter to allow a greater play of sun on the north terrace and kitchen wall. As an integral part of the house structure it could also act as a support for an antenna not shown in the drawings. Plate XII shows a horizontal louver system which shades the window until the sun reaches a position in the western sky whereby it penetrates under the louvers and must be supplemented by the screen.

Insulation

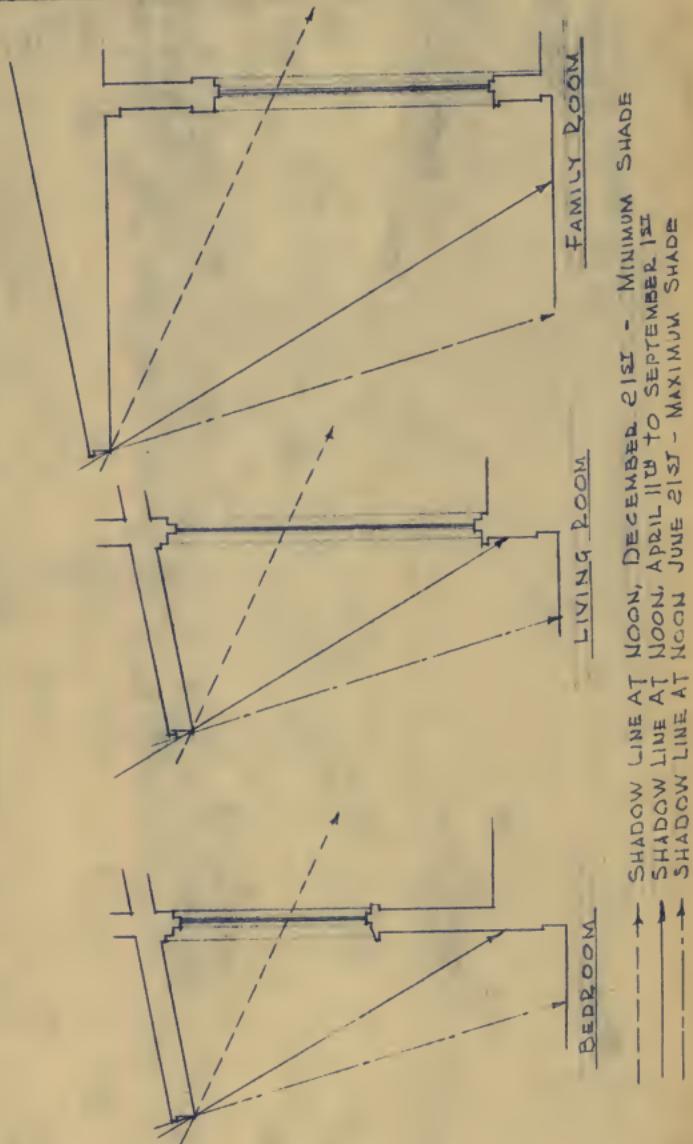
When designing the insulation for the house, it was clear that the extremes of temperature in Finney County made it necessary to provide all the insulation possible within practical means. Unlike the decision to concentrate on protection against summer heat as was done in the design of the roof structure, the insulation was designed to protect against climate factors present in winter as well.

For economy of winter fuel, an investigation of fuel costs indicated

EXPLANATION OF PLATE X

Illustration of shade on the south windows and
wall between April 11th and September 1st.

SUN CONTROL ON SOUTH

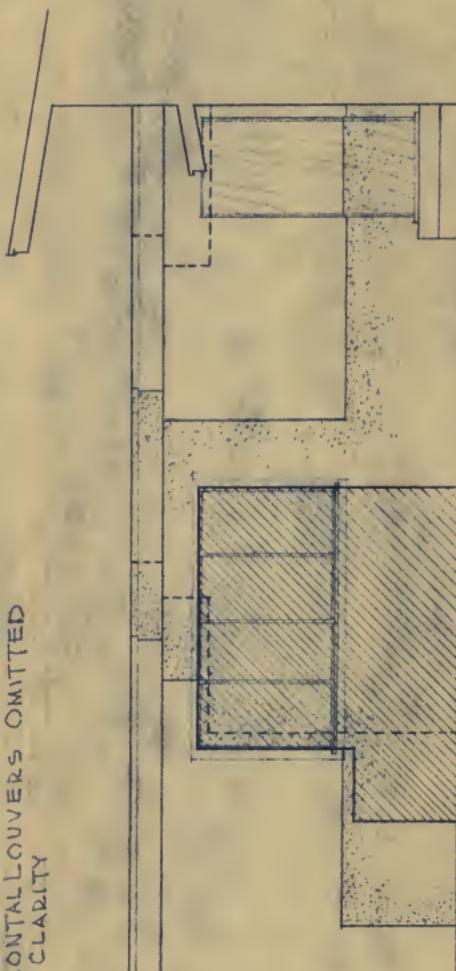


EXPLANATION OF PLATE XI

Shade on kitchen windows.

PLATE XI

NOTE. HORIZONTAL LOUVERS OMITTED
FOR CLARITY



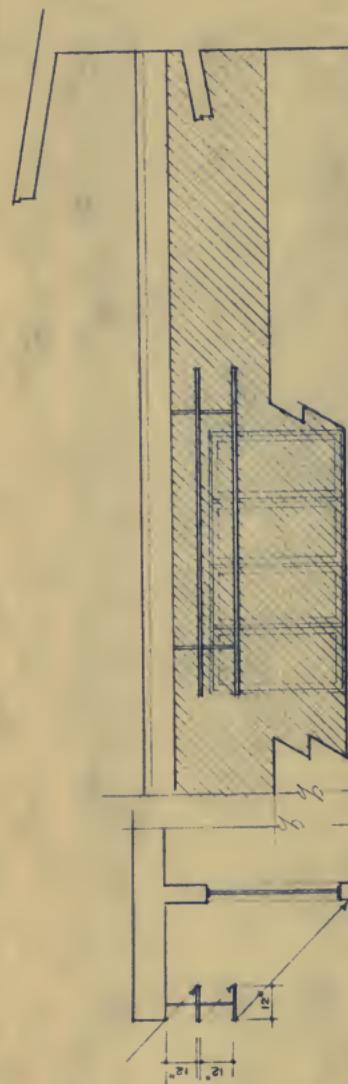
AFTERNOON SHADE ON KITCHEN
APRIL 11th AND SEPT 1st

APRIL 11TH AND SEPT 1ST

4:00 P.M.

5:00 P.M.

6:00 P.M.



SHADE ON KITCHEN WINDOW
CAST BY HORIZONTAL LOUVER

3:00 P.M. APRIL 11th TO SEPT. 1st

the use of electricity as a heating fuel to be the most costly. Therefore insulation values of the National Electrical Manufacturers Association were used as a guide. The N.E.M.A. recommended a "U" value of .07 in the ceiling, .082 in the walls and .10 in the floors with unheated basements, and .07 in floors over a vented crawl space. In the house concerned with in this thesis, there was no unheated basement, the only portion not being over a heated basement was the kitchen, utility wing which was over a vented crawl space and the family room which had a concrete floor east on the ground. Within the bounds of economy, these "U" values were exceeded to further economize on summer cooling loads.

There were seven types of structures needing insulation:

1. frame wall of 2 x 4 studs
2. frame wall with masonry veneer
3. masonry wall
4. ceiling under vented attic space
5. ceiling under flat roof
6. floor over vented crawl space
7. concrete slab on the ground

Plates XIII and XIV show the insulation placed in each of these seven areas.

The full thickness of insulation was chosen for the frame wall because studies (4, 10, 11, 16) indicated its economy over other methods. This type of insulation, without a reflective wrap, will give more insulation for the money expended. To take advantage of a reflective wrapping a 2" batt would have to be used to provide sufficient air spaces for the surfaces and the "U" value would be increased to .0622. The very slight extra cost of the 3 5/8" batt made it the better choice. In the case of the frame wall the recommendation of the N.E.M.A. was far exceeded. The exterior of fir tongue and groove was chosen because a light color was desired to hold down solar heating of the surface (5) and it was felt that painting a more expensive wood such

EXPLANATION OF PLATE XIII

Insulation in wall and ceiling.

PLATE XIII

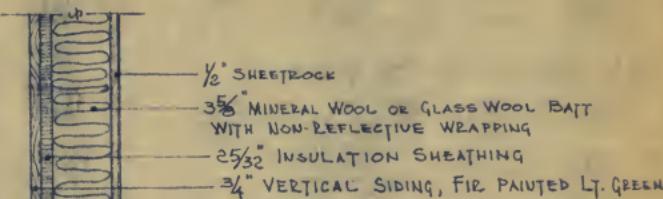


FIGURE 1.
FRAME WALL
 U VALUE = .056

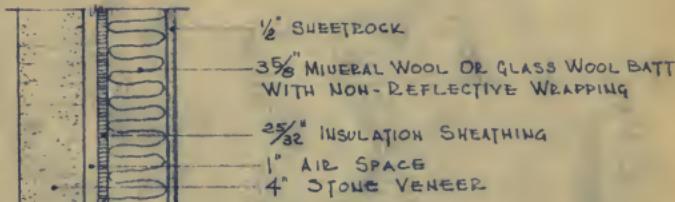


FIGURE 2.
FRAME WALL WITH STONE VENEER
 U VALUE = .0515

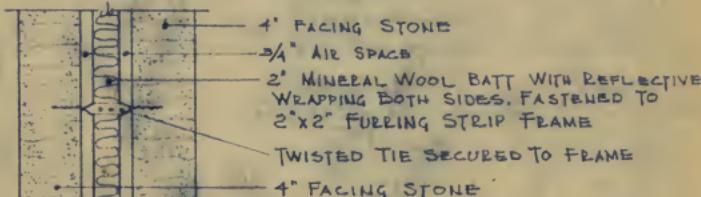


FIGURE 3.
MASONRY WALL
 U VALUE = .001

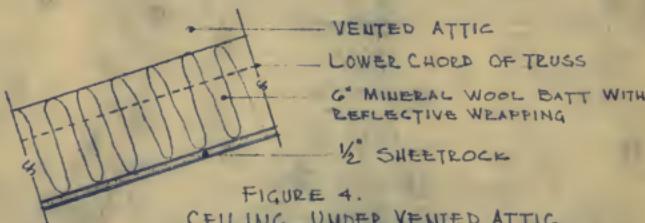


FIGURE 4.
CEILING UNDER VENTED ATTIC
 U VALUE = .0425

EXPLANATION OF PLATE XIV

Insulation in ceiling and floor.

PLATE XIV

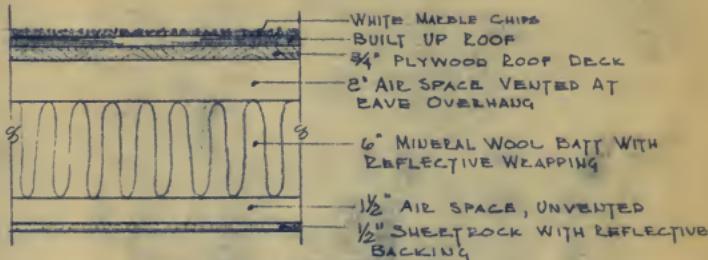


FIGURE 1.
CEILING UNDER FLAT DECK
U VALUE = .03B2

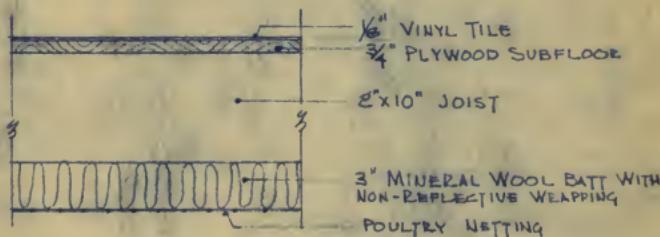


FIGURE 2.
FLOOR OVER VENTED CRAWL SPACE
U VALUE = .072

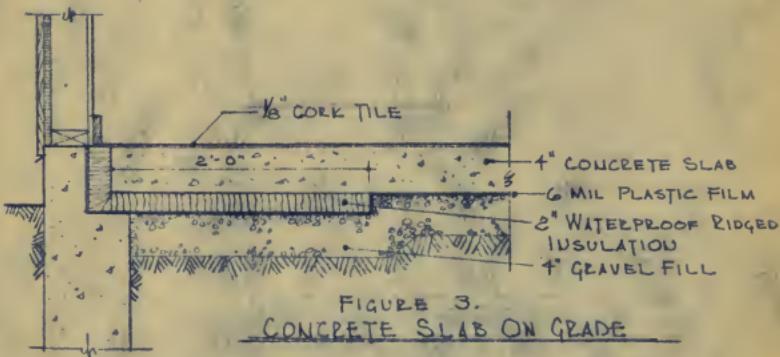


FIGURE 3.
CONCRETE SLAB ON GRADE

as redwood was not economically desirable.

When the frame wall was covered with a 4" stone veneer, the "U" value of the wall dropped only to .0515 from .056 and this did not warrant changing the thickness or type of insulation.

Due to the very poor thermal resistance of stone, the masonry wall was very difficult to bring within an acceptable "U" value limit. It would have been relatively simple to veneer an insulated frame wall as above, however, for the interior effect, a stone wall on the inside was desired. By placing a frame of 2" x 2" furring strips in a 3 1/2" cavity a value of .081 was obtained when the frame was filled with a 2" mineral wool batt. This batt had to have a reflective wrapping on both sides to get this value. Although a 3" layer of foamed plastic insulation could have been substituted for the furring and batt the cost would have been approximately seven times higher, the cost of the furring and batt averaging around 7.60 cents per square foot and the 3" foamed plastic around 51 cents per square foot.

By placing a 6" batt between the 2 X 4 members of the lower cord of the truss, the ceiling under the vented attic air space was given a "U" value of .0425. This is far superior to the recommendation of the N.E.M.A. and, in fact, is slightly better than their recommendation for a ceiling backing up an electrical radiant heating panel. The batt was wrapped with a reflective material even though the side next to the interior will be ineffective. It was felt that the extra cost was warranted because of the value in reflecting heat radiated by the roof. The use of the 6" batt also had the advantage of achieving this low "U" value and still using a product that is readily available in the area.

Since the attic is expected to contain moving air, the total roof

structure was not included in the insulation calculations, however, a value was given the exterior surface of the insulation equal to the standard given an exterior surface exposed to a 15 mile per hour wind.

To further reduce the heat gain through radiated heat from the roof, a layer of aluminum foil-draft paper laminate was placed directly on this under surface of the top cords of the truss. This reflective insulation not only will reduce the radiated energy but will help reduce the temperature of the attic air. The reflective material should be perforated at several points between structural members to prevent moisture condensation between it and the roof sheathing. The insulative value of the roof insulation is not to be used to calculate heat loads for cooling equipment, but is intended to reduce cost of operation.

In insulating the flat roof over the kitchen, the procedure was made the same with some exceptions. Because of the doubtful value of the ventilation in the air space above the 6" batt to reduce the temperature of that space it was necessary to increase the value of the insulation at the lowest cost possible. This was done by recessing the batt 1 1/2 inches (to allow for sagging) above a reflective backed sheet rock ceiling. The resulting reflective air space gave a "U" value of .0382 for both summer and winter. The roof structure above the insulation was not included in the calculations since the space between it and the insulation is not dead air. However, to reduce heat gain the built up roof was surfaced with white marble chips. Due to the absence of the sun on some days the reflective value of these chips cannot be applied to heat gain figures when applied to the size of cooling equipment.

The kitchen and service area is built over an unheated, vented crawl

space, therefore insulation is necessary in the floor to assure comfort on that surface. Heat gain from the crawl space is small in the summer, but heat loss in the winter, although small compared to walls and ceiling, is enough to warrant some insulation. The N.E.M.A. requirement is easily met with a 3" mineral wool batt.

The floor in the family room is constructed with a concrete slab on grade which was insulated with 2" of waterproof rigid insulation at the edge and extending under the slab as a 2" border around the perimeter.

Tests by the Small Homes Council (2) recommends this type of insulation not because of the amount of heat lost through the floor, but because it was found to maintain a more comfortable floor temperature. Heat loss through a slab floor of this kind was found to be a very small part of the total heat loss in a building.

Landscaping

When designing a home with regard to controlling the climate, the plant material that surrounds the house can no more be separated from the problem than the structure separated from the site itself. Plate XV shows the landscaping recommended for this home that has as its purpose the control of climatic factors. Landscaping for decorative purposes has been omitted.

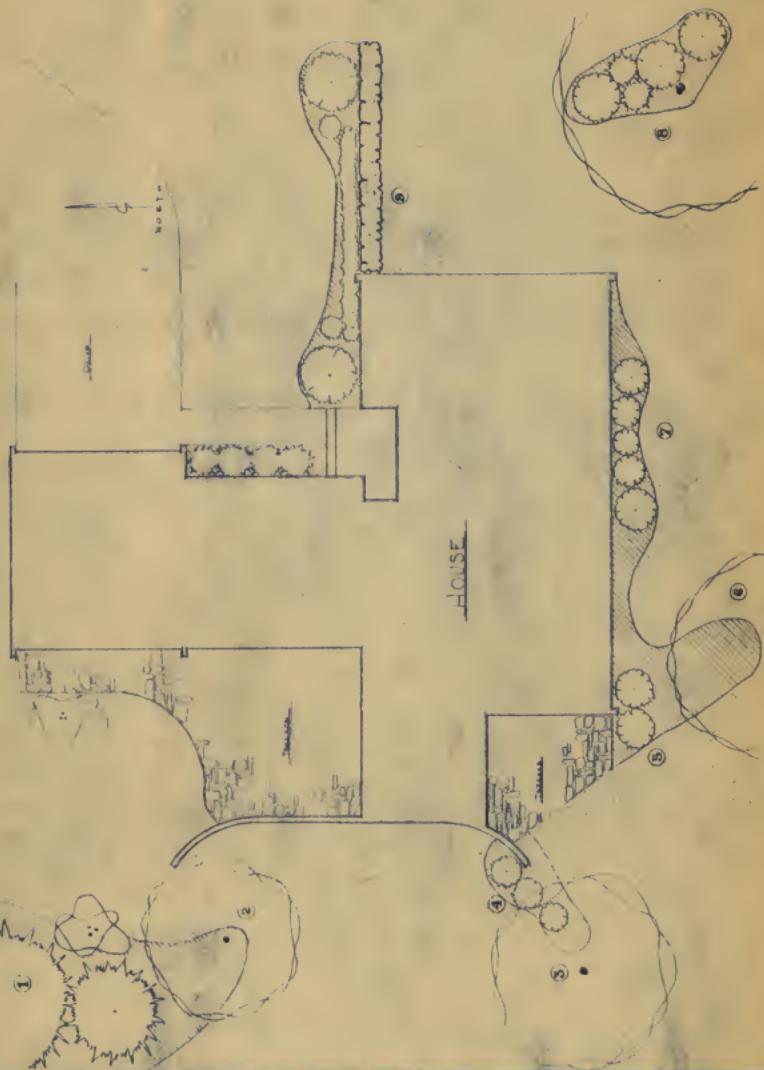
Planting in Area #1 is comprised of evergreens, mixed pines and cedars. This thick all season foliage serves two purposes; first to protect the rear patio and rear entrance from northwest winter winds, and second to serve as a sun screen for the patio at sunset in the summer.

Trees #2 and #3 are deciduous with a mature height of 30 to 40 feet and serve as a summer shade for the patios and south family room windows.

EXPLANATION OF PLATE XV

Landscape Plan

PLATE XV



This is doubly important for the south patio since the flag stone surface would have a tendency to radiate a large amount of heat toward the house.

The plantings in Area #4 have a thick foliage and serve as an extension of the masonry wall. By doing so, they help to channel breezes from the south across the lawn toward the south windows for ventilation purposes and to move air out from under the large overhand over the patio.

Plantings #5 are used as a catch for leaves and trash and need not have a thick foliage.

Tree #6 serves as an earlier hour shade for the living room windows and the south patio.

Plantings #7 are of thick foliage and are located to boost ground breezes up toward the bedroom windows. Tests by the University of Texas (24) indicate a more complete ventilation of the room with this upward flow of air.

Area #8 contains mixed evergreen and deciduous shrubs designed to help channel southern breezes toward the east bedroom window. The shrubs should be at least four to five feet in height to be effective.

Hedge #9, studies (24) indicate, if the foliage is heavy and a height of five feet is attained, can form an area of high pressure which will escape into a low pressure area. In this case the low pressure exists inside the house and through this process the north-east bedroom may be ventilated as illustrated in Plate XVI.

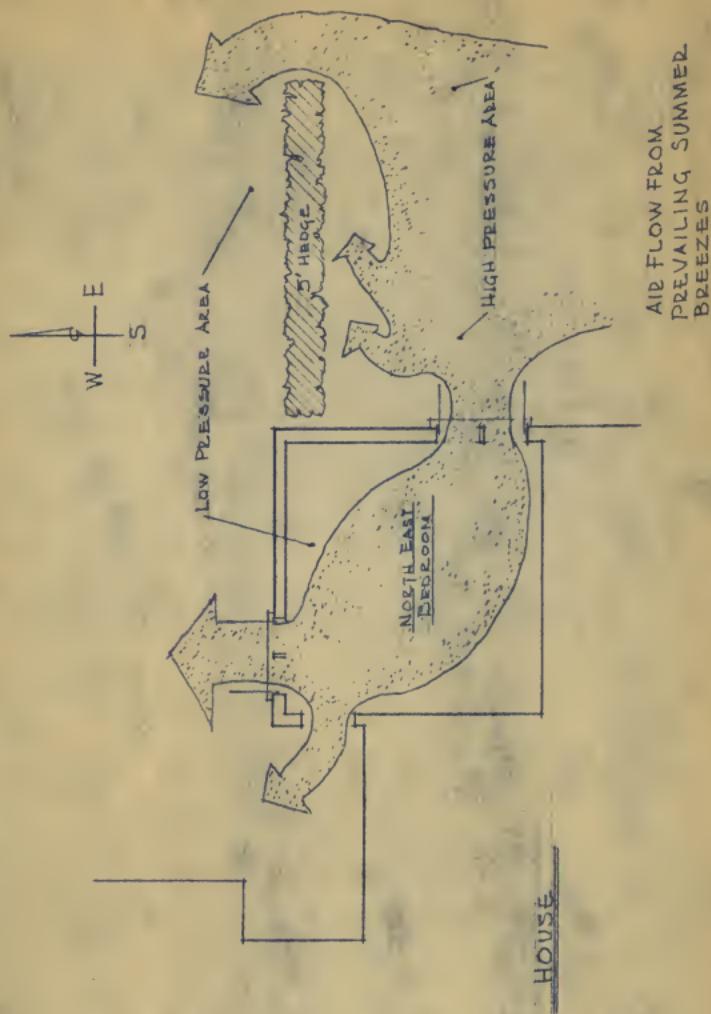
SUMMARY

As stated at the beginning of this thesis the proposed house design for a family in Finney County, Kansas by no means constitutes the authors idea of a prototype climate control house. The home, in fact, may have

EXPLANATION OF PLATE XVI

Ventilation effect of hedge.

PLATE XVI



features that would be at odds with the desires of many families. In an attempt to use the design of the home as a tool for controlling climate it is possible that too many varied elements were allowed to enter the total design for the sake of example. However, even with these various examples of climate control procedure, it is possible to conclude that a home designed for the hot sun, high winds and cool nights of western Kansas need not and probably will not resemble homes borrowed from other areas.

The thesis pointed out one of the major problems in this area, that of excessive summer heat gain, and offered a possible solution. Although the ventilation in the truss ends is not a solution in itself it points out that ventilation of attic space must consist of more than a commercial vent in each gable end or a row of screened vents in a hip roof eave line. The idea of a double roof is not a new one. This type of construction has been used successfully in warm climates although western Kansas, up to now, has not been considered in the category. Construction of the second roof need not always follow the design of the one in this thesis. Other possibilities might be light metal tents or awnings suspended over the permanent water proof roof. The top roof or cover might not even be water proof but of necessity it would have to be wind proof.

No attempt has been made to calculate the heating or cooling loads on the home or to design a mechanical system to take care of it. In fact no one type of heating system, fuel or cooling apparatus has been recommended. Also no attempt was made in such a short thesis to duplicate technical material previously published on climate control processes not deemed desirable in this problem such as water cooled roofs, pools, solar collectors, various insulating materials, etc. Instead, the intent was to point out by,

going through the process, how available climate data, tests, studies and research may be applied to climate control through design of the Kansas home.

ACKNOWLEDGMENT

The author wishes to express his appreciation to Professor Emil C. Fischer for his suggestions and assistance in directing this study, to Associate Professor Jack Durgan and Mr. Chester Davis, U. S. Department of Agriculture of their suggestions and help in directing investigation of solar controls, and to Professor L. R. Quinlan for helpful guidance and information on the phase of landscaping.

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CLIMATE CONTROL IN DESIGN OF THE KANSAS HOME

by

DALE E. SCHINDLER

B. S., Kansas State University, 1953

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Architecture

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1960

Over the past one hundred and fifty years, houses in Kansas have been designed and constructed with apparent disregard to some of the major climate problems present in the state. Too many times the homes, although reflecting the prairies of the state, do not represent a structure designed any more for Kansas climate than the Cape Cod cottage or the Swiss mountain lodge. This study shows the method whereby using climate data available, a house may be designed which utilizes this climate and reflects its use in its appearance.

The study was made for a certain location in Kansas, Finney County. A site was chosen and a problem was drawn up. Then considerable investigation into the climate of Finney County was made, with data recorded on temperature, solar energy, wind, precipitation and other climatic factors such as relative humidity and dust storms.

The house was designed and an analysis of design was made in terms of climate control. In plan, the house took into consideration the north winds by protecting the major portion of the house and the entrance behind the garage. Major window openings were on the south because of ease of solar control. The only openings on the west were in the kitchen area and these were protected by an off the building sun shade.

Primary consideration was given the control of summer heat by design of the roof structure. Roof types available were investigated and the conclusion drawn that although an attic space was desirable, most of them had the one disadvantage of storing overheated air and were difficult to ventilate. Because of the orientation of the house, with its long axis east and west, ventilation at the gable ends had the further disadvantage of not catching the summer breezes from the south. Therefore, a roof structure was devised

from a butterfly truss which opened the attic space along the entire south side. This truss also provided a venturi effect at the center which would tend to draw air out of the house and thereby change the air in that portion of the building while taking the heated air out of the attic.

A study of insulation was made and recommended practices noted. The effect of landscaping was shown.

The resulting house was not intended to represent a prototype house for all of Kansas, and in fact may have features that would be undesirable to many families. In an attempt to use the design of the house as a tool for controlling climate, it is possible that too many varied elements were allowed to enter the total design for sake of example. However, with these various examples of climate control procedure, it is possible to conclude that a home designed for the hot sun, high winds and cool nights of Western Kansas need not and probably will not resemble homes borrowed from other areas.

This thesis pointed out one of the major problems in this area, that of excessive summer heat gain, and offered a possible solution. No attempt was made to calculate heating or cooling loads. Many climate control processes well covered in other publications but not deemed desirable for this house were left out. Instead, the intent was to point out by going through the process, how available climate data, tests, studies and research may be applied to climate control through design of the Kansas home.